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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Synergetic aerosol retrieval from SCIAMACHY and AATSR onboard ENVISAT" *by* T. Holzer-Popp et al.

T. Holzer-Popp et al.

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Response by the authors to referee number 1

Dear reviewer,

We are thankful for your comments which are in deed very helpful to improve our paper.

Response to General comments

Added value of the synergy of the 2 instruments used We do use for the AOD retrieval AATSR measurements only from the 670 nm channel over land since we want to avoid lower accuracy in characterizing surface reflectance at 550 nm end even more at 870 nm which are both affected by chlorophyll variability and therefore have weaker correlation with the 1.6 micron band. We did not use the dual view capability due to co-registration errors in rugged terrain From SCIAMACHY we exploit 10 wavelengths

(though not all linear independent) because this provides higher accuracy and higher information content (as shown); of course, the draw back is in the large pixel size, but the gain is the capability to retrieve “more than AOD + Angstrom coefficient” – this is true as the 40 aerosol types have typically bi-modal size distributions – to our knowledge mixing of basic components can not be retrieved with AATSR. This is the reason that we use the second instrument SCIAMACHY to estimate aerosol composition (not “just” Angstrom coefficient, which assumes a mono-modal aerosol model and does not take into account different absorption features – see below). Cloud contamination is dealt with by rigid cloud detection on 1km grid (which is then spatially integrated to SCIAMACHY) and by the cloud correction of SCIAMCHY pixels as described in Holzer-Popp, et al. 2002a. Also the different scales and spatial integration of the 2 instruments are sensitive to the choice of the aerosol type (different single scattering albedo means different atmospheric effects for low and high surface reflectances due to non-linear radiative transfer) – thus also for highly variable surface reflectance inside a SCIAMCHY pixel the spatial integration leads to different results and thus different fit error (assuming a homogeneous aerosol load inside the entire SCIAMACHY pixel). Only this last feature allows the differentiation between different absorption properties of aerosol components. However, a theoretical quantification of this effect seems very difficult to us.

Surface reflectance and dark fields There are 2 thresholds with regard to surface brightness in our retrieval scheme: - The first one (set to 0.085 at 670 nm) applies to the first retrieval step for 1km AATSR dark fields (where the NDVI-dependent correlation with the 1.6 micron channel surface reflectance is exploited) which are used for AOD retrieval. Then using the retrieved AOD at the dark fields, spatial interpolation to all 1km pixels is conducted (triangulation). With this complete AOD image we conduct then atmospheric correction (for each of the 40 mixtures assuming a selected aerosol model) using the same radiative transfer model to obtain surface reflectances for each cloud-free 1km pixel at 3 wavelengths of 550, 670, 870 nm and thus also NDVI and CVI. - A

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2nd surface reflectance threshold (set at 0.20 at 670 nm during validation) is analysed for the second retrieval step using the 60x30 km2 SCIAMACHY pixels. In this step, based on knowing AOD and surface albedo and selected surface type (from NDVI, CVI, brightness) from the first retrieval step, a choice between simulated spectra for 40 mixtures is made. Here a brighter threshold (as compared to step 1) is possible and here the extension in application to brighter surface reflectances is made against version 1.0 (the appropriate limit was 0.15). The information content analysis shows with the example of bare soil, that this second step has less degrees of freedom for brighter surfaces, but is still applicable to some extent; only over extremely bright surfaces such as snow, there is no information content on aerosol type at all (due to the higher noise level of bright surfaces).

Due to the vegetation-dependence (as similarly treated for MODIS collection 5) of the correlation of 1.6 micron with the 670 nm channel we have made a large effort (described in section 3.3. which is not targeted at using brighter surfaces for the AATSR AOD retrieval) to improve the accuracy and global applicability of this dark field approach – our goal was never to treat bright surfaces with this step, which would require a completely different approach (e.g. using surface reflectance databases for dry regions).

Consequently, the statement in the conclusion will be extended to say, that we can use the method also over moderately dark surfaces if there are few dark spots suitable for the 1km AOD retrieval within the larger spectrometer pixel.

Information content By theory using AATSR 2 bands (due to the low sensitivity over bright surface albedo we do not think that the 870 nm band is useful) only a maximum total DOF value (including AOD and surface reflectance) of 2 would be possible. The purpose of this analysis in our manuscript is to establish theoretically the information content of step 2 in our retrieval, namely the choice of the most plausible aerosol mixture by using the 10 wavelengths of SCIAMACHY. We are convinced that both the information content analysis and the validation show that there is more information in

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the combination of both instruments, which allows to estimate aerosol composition and for favourable conditions retrieve up to 5 DOF in total. As shown with the example of soil surface brightness can be also of non-dark surface if the first step to retrieve AOD and surface reflectance can be conducted (i.e. few dark 1km pixels are within the SCIAMACHY pixel).

Response to Detailed comments

(our responses are marked by < >)

p. 2910, line 17: why in lower troposphere and not column integrated? How about disconnected layers with different aerosol content? Please provide references for AOD in free troposphere and stratosphere <We base our retrieval on the fact that in most cases the majority of AOD is in the boundary layer or in an additional elevated dust layer. Therefore, we only alter these 2 layers in our retrieval keeping the rest of the column fixed (and restricting ourselves to periods outside volcanic activity). Admittedly, multi-layer structures are not captured by our approach – text will be improved Reference for AOD in troposphere and stratosphere will be added (World Climate Program, 1986)>

p. 2911, line 11: how is established that the correct AOD is delivered? <“Correct” means here the value retrieved for the aerosol mixture which is selected – text will be improved.>

Line 20: what is very weak sampling? <This refers to the fact, that small GOME swath pixels (80x40 km2, otherwise the braod swath had pixels of 320x40 km2) were only acquired on 3 days of each month for most of the ERS-2 mission – text will be improved.>

p. 2912, line 4: is it 52 or 55 degrees as is often mentioned in the literature <We have checked the basic technical publications and will correct this value to 55 degrees.>

p. 2913, line 9: remove been <This will be done.>

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line 10: which RT code? <We use an extended SOS as specified in Holzer-Popp et al. 2002a – this will be added to the manuscript.>

line 22: retrieval is an ill-posed problem with lack of information, so why do the authors state here that there is too much information? <Our statement wants to say that for spectrometer instruments there are too many bands (e.g. for SCIAMACHY over 5000), which are strongly dependent and there are technical limitations to deal with unselected spectra – this will be reworded.>

p. 2916, line 2: depends line 10 obviously line 13: field <These errors will be corrected.>

p. 2924, line 18: intervals <This error will be corrected.>

p. 2925, line 16: mis-distance/miss-time: suggest to use temporal and spatial differences? <We will follow your suggestion.>

p. 2926, line 6 and following paragraphs: what is meant with mis-interpretations … comparisons: isn’t the aerosol variability the reason why commonly only data are considered which were collected within a narrow time and spatial window? This may still go wrong in cases of strong local gradients, but this will not improve by the analysis described in section 4.1. I seem to miss the point of the variogram analysis: what is the interpretation of Figure 8? Would one really expect any correlation between highly variable parameters such as aerosols measured 1000 or more km apart? What does it mean when, e.g., RSME=01 and then doubles? RSME for stations 2000 km apart in different continents are very different, why? Please explain the significance of this analysis and how we can interpret it. In general, I would expect that particles in the accumulation mode, which determine AOD at 550 nm, have an infinite lifetime (cf. Hoppel et al., 2002, 2005, full refs below) and hence their concentrations are mainly affected by washout or by emissions. However, because of the very large SYNAER pixels size, the analysis of the correlations over 50 km is relevant (this underlines my general question why SCIAMACHY is needed in addition

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to AATSR). <If aerosol spatial-temporal high variability is not considered in validating satellite pixel (i.e. area averaged) results with station measurements (i.e. spot values), a miss-interpreatation can be done that the high RMSE values are solely due to the inaccuracies of the satellite retrieval method and its assumptions. The purpose of this section is thus to provide a quantitative estimate of the lowest RMSE possible when comparing the large SCIAMACHY pixel results to AERONET stations. The provided order of magnitude value of 0.05 to 0.1 (depending on region) shows that this is relevant when judging the AERONET validation of our method. We have used the available AERONET stations for 3 regions to show spatial de-correlation with increasing distance between 2 station measurements at the same time. For large distance, where no spatial correlation is expected the interpretation is indeed difficult (similarity of aerosol regimes between far off regions?). However, for small distances the graph shows the dependence of this spatial variability on region and allows to characterize the noise in a SCIAMACHY pixel and thus also against an AERONET observation which is due to atmospheric variability and not due to retrieval inaccuracies.>

p. 2928, line 1: Figs 11 and 12: somewhere figure count went wrong since here we see Figure 10 and 11. However, these figures are too small to see the features discussed (lines 15 and further, Figure 10 caption, colour scale is virtually invisible on both Figures line 2: this article is on improvement and upgrade from version 1.0 to version 2.0. Since version 2.0 processing was started, why don’t the authors present results from v2.0 and /or show what the improvement is by comparison of v1.0 withv2.0? I’d expect significant improvement, why else is a new version needed? <The figure counts will be corrected and the figures will be improved technically (colour scale, size. We have now processed the relevant version 2.0 data and will exchange the figures to version 2.0 plus add selected figure 1.0 figures to document the changes. Also bias/standard deviation values for both versions 1.0 and 2.0 will be stated to prove the impact of the improvements (version 1.0 the respective values for 440, 550, 670 nm were obtained with 43 pixels of the same period/test orbits were: bias: -0.02, 0.03, 0.03; stdv: 0.15, 0.18, 0.14)> .

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p. 2929, line 12: what is meant with These features are precluded? Isn’t AOD the integral over the whole column? line 22-23: indications on composition were also published in Robles-Gonzalez (JGR, 2006, 2007). line 25: Ångström coefficients seem to be the only criterium to select composition. Hence a comparison could be made with AERONET. I did not see such comparison in this paper. <Line 12: we want to say that these features are not as clearly visible in total AOD (which is the sum of all components) and in the soot component these features can be better seen. Line 22: we will add this reference to the state of the art overview Line 25: as we do not retrieve the Angstrom coefficient (see response to general remarks) we did not conduct such an inter-comparison – also the spatial variability of the Angstrom coefficient when doing pixel-point comparisons could be critical.>

p. 2930, lines 7-16: why were sites used for comparison which are clearly not suitable due to strong local variations? <We wanted to optimize the number of available coincidences and include interesting cases. Also not in all cases could we assess the representativity of a station. One extreme case we have excluded (due to altitude). We intend future research to use high spatial resolution auxiliary information (e.g. elevation, population density, emission inventory) to investigate the representativity of a measurement with a standardized approach. The validation result which includes the remaining “bad cases” is thus satisfactory.>

p. 2931, line 25: the limitation to spherical particles is not necessary since good approximations are available for the phase function of dust particles and have been used to improve the retrieval (POLDER). <We wanted to limit the complexity of our aerosol model (which is already rather complex with 9 components and 40 mixtures) since we do not have particular sensitivity to non-sphericity (as e.g. MISR or POLDER/PARASOL do have). Using an effective non-spherical phase function for desert dust is clearly one future potential improvement.>

References World Climate Program (WCP), 1986: A Preliminary Cloudless Standard Atmosphere for Radiation Computation, WCP-112, WMO/TD No. 24, Boulder.

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Holzer-Popp, T., Schroedter, M., and Gesell, G., 2002a: Retrieving aerosol optical depth and type in the boundary layer over land and ocean from simultaneous GOME spectrometer and ATSR-2 radiometer measurements, 1, Method description, J. Geophys. Res., 107, D21, AAC16-1 – AAC16-17.

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